

## CHM129

①

## Problem Set #12

## (1) (a) Pure water

$$\text{Adding HCl} \Rightarrow [\text{H}_3\text{O}^+] = [\text{HCl}] = \frac{0.010 \text{ mol}}{0.500 \text{ L}} = 0.020 \text{ M HCl}$$

$$\text{pH} = -\log(0.020) = 1.70$$

Initial pH

of pure  
water is 7.00

$$\text{Adding NaOH} \Rightarrow [\text{OH}^-] = [\text{NaOH}] = \frac{0.010 \text{ mol}}{0.500 \text{ L}} = 0.020 \text{ M NaOH}$$

$$\text{pOH} = -\log(0.020) = 1.70$$

$$\text{pH} = 14.00 - 1.70 = 12.30$$

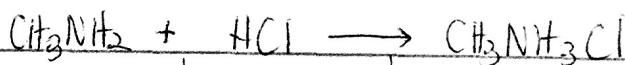
## (b) Initial pH:

$$\begin{aligned} K_b \text{ of } \text{CH}_3\text{NH}_2 &= 4.4 \times 10^{-4} \\ \text{Ka of } \text{CH}_3\text{NH}_3^+ &= 1.0 \times 10^{-14} \\ &\quad 4.4 \times 10^{-4} \\ \text{Ka} &= 2.3 \times 10^{-11} \end{aligned}$$

$$\text{pH} = \text{pK}_a + \log \frac{[\text{base}]}{[\text{acid}]} = -\log(2.3 \times 10^{-11}) + \log \frac{(0.155)}{(0.045)}$$

$$\text{pH} = 10.67$$

## \* Adding HCl:



BA	0.0775 mol		0.0725 mol
A		0.010 mol	
AA	0.0675 mol	0	0.0825 mol

$$\text{pH} = -\log(2.3 \times 10^{-11}) + \log \frac{(0.0675)}{(0.0825)} = 10.55$$

## \* Adding NaOH:



BA	0.0725 mol		0.0775 mol
A		0.010 mol	
AA	0.0625 mol	0	0.0875 mol

$$\text{pH} = -\log(2.3 \times 10^{-11}) + \log \frac{(0.0625)}{(0.0875)} = 10.78$$

(2)

(c) Initial pH:

$$\text{pH} = \text{pK}_a + \log \frac{[\text{base}]}{[\text{acid}]} = -\log(1.1 \times 10^{-2}) + \log \frac{(0.115)}{(0.125)}$$

$K_a \text{ of HClO}_2 = 1.1 \times 10^{-2}$

$$\text{pH} = 1.92$$

\* Adding HCl:

BA	0.0575 mol		0.0625 mol	
A		0.010 mol		
AA	0.0475 mol		0.0725 mol	

$$\text{pH} = -\log(1.1 \times 10^{-2}) + \log \frac{(0.0475)}{(0.0725)} = 1.77$$

\* Adding NaOH:

BA	0.0625 mol		0.0575 mol	
A		0.010 mol		
AA	0.0725 mol		0.0675 mol	

$$\text{pH} = -\log(1.1 \times 10^{-2}) + \log \frac{(0.0675)}{(0.0725)} = 1.93$$

## (2) Strong acid - Strong base titration

$$V_e = V_b = \frac{C_a V_a}{C_b} = \frac{(0.150 \text{ M})(20.0 \text{ mL})}{(0.200 \text{ M})} = 15.0 \text{ mL RbOH}$$

(a)  $V_b = 0 \text{ mL RbOH}$  (Strong acid soln)

$$[\text{H}_3\text{O}^+] = [\text{HN}_3] = 0.150 \text{ M}$$

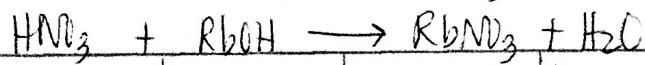
$$\text{pH} = -\log(0.150) = 0.824$$

(3)

(b)  $V_b = 10.0 \text{ mL RbOH}$  (Remaining strong acid soln)

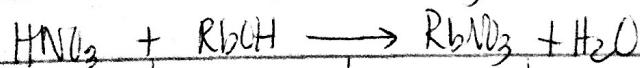
BA	3.00 mmol			
A		2.00 mmol		
AA	1.00 mmol	0	2.00 mmol	

$$[\text{H}_3\text{O}^+] = [\text{HNO}_3] = \frac{1.00 \text{ mmol}}{30.0 \text{ mL}} = 0.0333 \text{ M} \quad \text{pH} = -\log(0.0333) = \underline{\underline{1.477}}$$

(c)  $V_b = 20.0 \text{ mL RbOH}$  (Excess strong base soln)

BA	3.00 mmol			
A		4.00 mmol		
AA	0	1.00 mmol	3.00 mmol	

$$[\text{OH}^-] = [\text{RbOH}] = \frac{1.00 \text{ mmol}}{40.0 \text{ mL}} = 0.0250 \text{ M} \quad \text{pOH} = -\log(0.0250) = \underline{\underline{1.60}} \\ \text{pH} = 14.00 - 1.60 = \underline{\underline{12.40}}$$

(d)  $V_b = 25.0 \text{ mL RbOH}$  (Excess strong base soln)

BA	3.00 mmol			
A		5.00 mmol		
AA	0	2.00 mmol	3.00 mmol	

$$[\text{OH}^-] = [\text{RbOH}] = \frac{2.00 \text{ mmol}}{45.0 \text{ mL}} = 0.0444 \text{ M} \quad \text{pOH} = -\log(0.0444) = \underline{\underline{1.35}} \\ \text{pH} = 14.00 - 1.35 = \underline{\underline{12.65}}$$

(4)

(e)  $V_b = 30.0 \text{ mL RbOH}$  (Excess Strong base soln.)

BA	3.00 mmol			
A		6.00 mmol		
AA	0	3.00 mmol	3.00 mmol	

$$[\text{OH}^-] = [\text{RbOH}] = \frac{3.00 \text{ mmol}}{50.0 \text{ mL}} = 0.060 \text{ M} \quad \text{pH} = -\log(0.060) = 1.22$$

$$\text{pH} = 14.00 - 1.22 = \underline{\underline{12.78}}$$

## (3) Weak acid - Strong base titration

$$V_e = V_b = \frac{C_a V_a}{C_b} = \frac{(0.130 \text{ M})(25.0 \text{ mL})}{0.250 \text{ M}} = 13.0 \text{ mL NaOH}$$

(a)  $V_b = 0 \text{ mL NaOH}$  (weak acid soln)

$$[\text{H}_3\text{O}^+] = \sqrt{K_a \times [\text{HF}]} = \sqrt{(6.8 \times 10^{-4})(0.130)} = 9.4 \times 10^{-3} \text{ M}$$

$$\text{pH} = -\log(9.4 \times 10^{-3}) = \underline{\underline{2.03}}$$

(b)  $V_b = 6.50 \text{ mL NaOH}$  (Buffer Region)

$$V_b = \frac{V_e}{2} \quad \text{midpoint of the titration}$$

$$\text{pH} = \text{p}K_a = -\log(6.8 \times 10^{-4}) = \underline{\underline{3.01}}$$

(c)  $V_b = 10.0 \text{ mL NaOH}$  (Buffer Region)

BA	3.24 mmol			
A		2.56 mmol		
AA	0.75 mmol	c	2.56 mmol	

→ Continue

(5)

$$\text{pH} = -\log(6.8 \times 10^{-4}) + \log \frac{(2.50)}{(0.75)} = 3.69$$

$\nwarrow F^- \text{ (base)}$   
 $\searrow HF \text{ (acid)}$

(J)  $V_b = 13.0 \text{ mL NaOH}$  (Equivalence Point - Weak base soln)



BA	3.25 mmol			
A		3.25 mmol		
AA	0	0	3.25 mmol	

$$[F^-] = \frac{3.25 \text{ mmol}}{38.0 \text{ mL}} = 0.0855 \text{ M} \quad K_b = \frac{1.0 \times 10^{-4}}{6.8 \times 10^{-4}} = 1.5 \times 10^{-11}$$

$$[\text{OH}^-] = \sqrt{K_b \times [F^-]} = \sqrt{(1.5 \times 10^{-11})(0.0855)} = 1.1 \times 10^{-6} \text{ M}$$

$$\text{pOH} = -\log(1.1 \times 10^{-6}) = 5.95 \quad \text{pH} = 14.00 - 5.95 = 8.05$$

(L)  $V_b = 20.0 \text{ mL NaOH}$  (Excess of Strong base soln)



BA	3.25 mmol			
A		5.00 mmol		
AA	0	1.75 mmol	3.25 mmol	

$$[\text{OH}^-] = [\text{NaOH}] = \frac{1.75 \text{ mmol}}{45.0 \text{ mL}} = 0.0389 \text{ M}$$

$$\text{pOH} = -\log(0.0389) = 1.41 \quad \text{pH} = 14.00 - 1.41 = 12.59$$

(M) Weak base - Strong acid titration

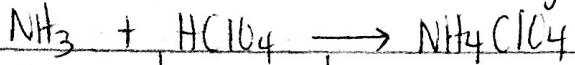
$$V_a = V_b = \frac{C_b V_b}{C_a} = \frac{(0.200 \text{ M})(30.0 \text{ mL})}{0.250 \text{ M}} = 24.0 \text{ mL HCl}$$

(6)

(a)  $V_a = 0 \text{ mL HClO}_4$  (weak base solution)

$$[\text{OH}^-] = \sqrt{K_b \times [\text{NH}_3]} = \sqrt{(1.8 \times 10^{-5})(0.200)} = 1.9 \times 10^{-3} \text{ M}$$

$$\text{pOH} = -\log(1.9 \times 10^{-3}) = 2.72 \quad \text{pH} = 14.00 - 2.72 = 11.28$$

(b)  $V_a = 10.0 \text{ mL HClO}_4$  (Buffer Region)

BA	6.00 mmol			$K_a \text{ of } \text{NH}_4^+$
A		2.50 mmol		$K_a = \frac{1.0 \times 10^{-14}}{1.8 \times 10^{-5}} = 5.6 \times 10^{-10}$
AA	3.50 mmol	0	2.50 mmol	

$$\text{pH} = -\log(5.6 \times 10^{-10}) + \log \frac{(3.50)}{(2.50)} = 9.40$$

 $\leftarrow \text{NH}_3 \text{ (base)}$  $\nwarrow \text{NH}_4^+ \text{ (acid)}$ (c)  $V_a = 12.0 \text{ mL HCl}$  (Buffer Region)

$$V_a = \frac{V_e}{2} \rightarrow \text{midpoint of the titration}$$

$$\text{pH} = \text{pK}_a = -\log(5.6 \times 10^{-10}) = 9.25$$

(d)  $V_a = 24.0 \text{ mL}$  (Equivalence Point - Weak acid solution)

BA	6.00 mmol		
A		6.00 mmol	
AA	0	0	6.00 mmol

$$[\text{NH}_4^+] = \frac{6.00 \text{ mmol}}{54.0 \text{ mL}} = 0.111 \text{ M}$$

$$[\text{H}_3\text{O}^+] = \sqrt{K_a \times [\text{NH}_4^+]} = \sqrt{(5.6 \times 10^{-10})(0.111)} = 7.9 \times 10^{-6} \text{ M}$$

$$\text{pH} = -\log(7.9 \times 10^{-6}) = 5.10$$

(7)

(e)  $V_a = 30.0 \text{ mL HClO}_4$  (Excess of Strong Acid Soln)



BA	6.06 mmol		
A		7.50 mmol	
AA	0	1.50 mmol	6.06 mmol

$$[\text{H}_3\text{O}^+] = [\text{HClO}_4] = \frac{1.50 \text{ mmol}}{60.0 \text{ mL}} = 0.0250 \text{ M}$$

$$\text{pH} = -\log(0.0250) = 1.602$$